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EFFECT OF NEW TRAILER DESIGNS ON TRANSIT TEMPERATURES OF SELECTED FROZEN FOODS

Frozen Pies and TV Dinners

Agricultural Marketing Service
Transportation and Facilities Research Division
UNITED STATES DEPARTMENT OF AGRICULTURE

AMS-446

PREFACE

This study is part of a broad program of research to improve the design and performance of transportation equipment used in the movement of agricultural products, as a means of improving and expanding the marketing of farm products.

Previous studies by industry and U.S. Department of Agriculture indicate that many refrigerated trailers now in service cannot maintain the required 0° F. temperature throughout all boxes in a load of frozen food. This report covers one of a number of test to determine the best features of late model types of equipment.

Cooperating in the test were Frozen Food Express and C. A. Swanson & Sons.

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Washington, D. C. June 1961

EFFECT OF NEW TRAILER DESIGNS ON TRANSIT TEMPERATURES OF SELECTED FROZEN FOODS

Frozen Pies and TV Dinners

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SUMMARY

In a test to evlauate the performance of two trailers with new developments in design and insulating techniques, both trailers did a relatively good job with loads of frozen pies and TV dinners. The trailers, labeled A and B, traveled between Omaha, Nebr., and Dallas, Tex. during the test.

The trailers were first precooled to 15° F. with dry ice; they were then loaded with frozen pies and TV dinners. At the end of the trip the average commodity temperatures in the two trailers were approximately the same, 4.0° F. in trailer A, and 4.5° F., in trailer B. Since A had a larger refrigeration unit of higher capacity this would indicate that B was more efficiently insulated. At destination, trailer A had a commodity temperature spread of 11.7 degrees as compared with only 5.0 degrees in trailer B. This would indicate that trailer B had better air circulation, due perhaps, in part at least, to its diagonal side wall ribbing, its greater air space under the load, and greater number of cross flow vent holes in the floor than trailer A.

In trailer A the maximum temperature of the product after loading fell from 16.5° F. to 7.5° F. by the following morning. Except for a 5¼ hour period following loading, the maximum product temperature was found at the bottom front side corners of the trailer. At unloading the maximum commodity temperature of 12.0° F. was 8.5 degrees above the average commodity temperature.

In trailer B the maximum temperature of the load fell from 11.5° F. after loading to 4.5° F. the following day and just before unloading had reached 7.5° F. The maximum product temperature in trailer B after loading was at the bottom front corner; 13 hours later it was at the top front corner, and at unloading time it was at the bottom rear corner. At 5:10 p.m. on June 22 and at unloading on June 23 the maximum commodity temperature was within 2.5 degrees of the average commodity temperature.

The average bottom commodity temperature in trailer B was generally lower throughout the trip than that of trailer A. This is probably due to a better distribution of chilled air and to the greater thickness of floor insulation in trailer B (6 inches as compared with 4 inches in trailer A).

These two trailers represent improvements in design and construction which will help carriers to maintain frozen foods closer to desired temperature than heretofore was possible. Additional tests will be made on other late

model equipment to determine those features of design that will help to maintain frozen foods at the recommended temperature of 0° F.

INTRODUCTION

Research has shown that frozen foods must be maintained at 0° F. or below in order to retain quality in storage over long periods of time. Since increases in product temperature result in cumulative effects which shorten the storage life of the frozen product, it is considered essential to maintain product temperatures at 0° F. while in transit from the processor to the consumer. The Association of Food and Drug Officials of the United States has proposed a code which would make it mandatory to maintain frozen foods at 0° F. in all phases of distribution.

The most recent designs in trailers provide more equal distribution of cooling air throughout the load and thus maintain more uniform temperatures. New, improved insulating techniques have been developed which, by reducing the amount of heat transfer, lowers the amount of refrigeration required to maintain satisfactory product temperatures.

A study of these trailers under actual operating conditions and a comparison of different designs will show that actual improvements have been made in controlling product temperatures during transit and also indicate the direction which new improved designs should take.

This transportation refrigeration test was conducted to compare two trailers which have incorporated some of the latest developments in improved trailer designs and insulating techniques.

DESCRIPTION OF TEST TRAILERS

Trailer A (fig. 1)

Body: Seven meat rails mounted lengthwise in the trailer; inside length 39 feet 4 inches; inside width 7 feet 1 inch; inside height 7 feet 1½ inches; 1,990 cubic feet; insulation, 4 inches of rigid foam in floor, 4 inches of glass fiber with vapor barrier in the sides and ends, 5 inches of glass fiber with vapor barrier in the roof; extruded aluminum floor with 1-3/4 inch deep grooves and crossflow vents on 6 inch centers; equipped with 1-7/8 inch floor racks; inside wall, plastic lining with 1 inch deep vertical ribbing on 6 inch centers.

Refrigeration unit: Mechanical diesel underslung unit, 7½ ton nominal rating (refrigeration capacity); evaporator fan air discharge rated at 3,600 cfm; canvas air distribution ducts, two each 10 feet in length by 5 inches by 5 inches, two each 20 feet in length by 5 inches by 5 inches, two each 30 feet in length by 5 inches by 5 inches.

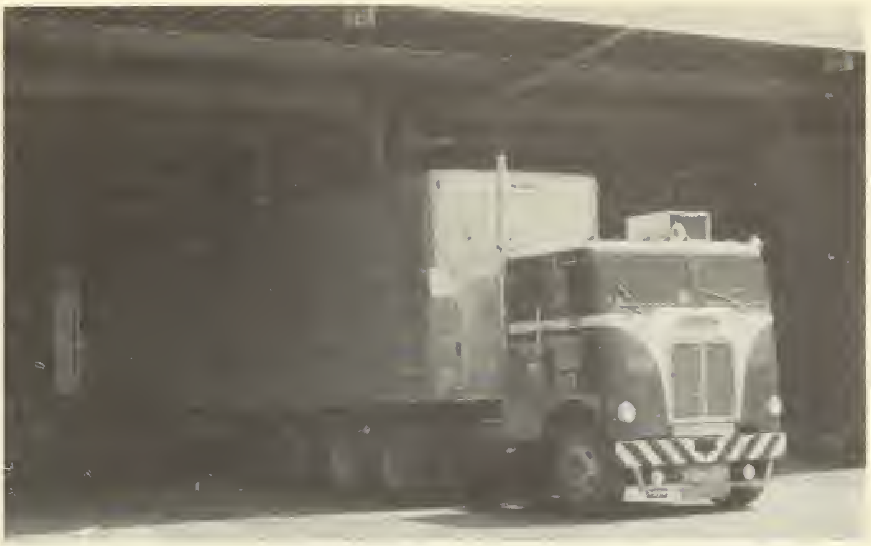

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Figure 1.--Trailer A.

Trailer B (fig. 2)

Body: Seven meat rails mounted lengthwise in the trailer; inside length 39 feet; inside width 7 feet 1-3/8 inches; inside height 7 feet 3 inches; 2,011 cubic feet; 6 inches foamed-in-place insulation with molded panels of styrene in floor; 4 inches of foamed-in-place insulation with molded panels of styrene in the sides and ends; 5 inches of foamed-in-place insulation with molded panels of styrene in the roof; 2-¼ inch extruded aluminum floor with cross flow vent holes on 2 inch centers; equipped with 1-7/8 inch floor racks; inside plastic wall lining with 1-inch deep diagonal ribbing sloping from top to bottom, toward the front of the trailer.

Refrigeration unit: Mechanical propane underslung unit, 5 ton nominal rating (refrigeration capacity); evaporator fan air discharge rated at 3,600 cfm; canvas air distribution ducts, two each 10 feet in length by 5 inches by 5 inches, two each 20 feet in length by 5 inches by 5 inches, two each 30 feet in length by 5 inches by 5 inches.

TEST PROCEDURE

The trailers were precooled to 15° F. with dry ice. The thermostats on both trailers were set at -10° F. before loading. Trailer A was loaded with 29,831 pounds of pies and TV dinners, trailer B with 33,653 pounds of pies and TV dinners. Nineteen thermocouples were installed in each trailer, 14 of which were used to indicate commodity temperatures, while the remaining 5 were used to indicate interior air temperatures. Readings were taken shortly after loading and at intervals varying from 3 to 6 hours during transit from Omaha, Nebr., to

Dallas, Tex. Both trailers stayed together throughout the trip from Omaha to Dallas; one trailer unloaded near Dallas, the other proceeding on to Houston, Tex. Data were taken just before the unloading of each trailer.

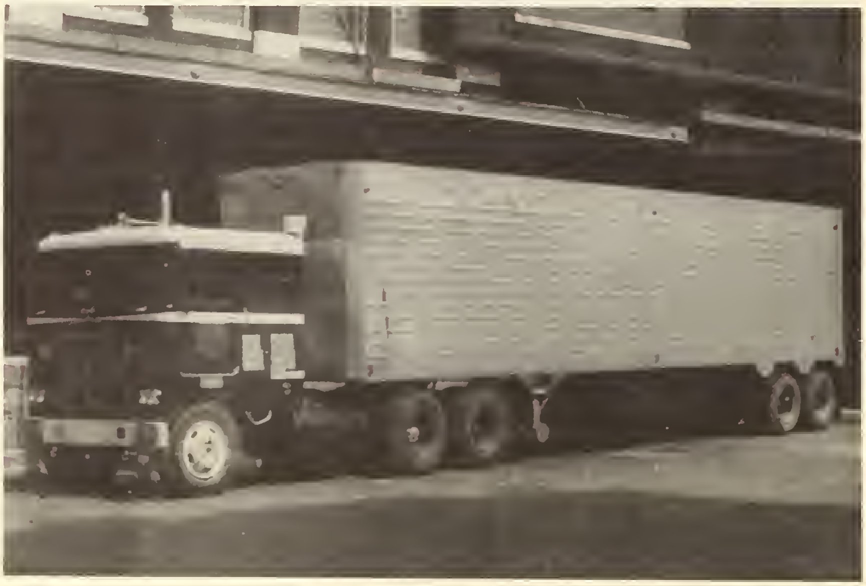

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Figure 2.--Trailer B.

Each thermocouple used to indicate the commodity temperature was placed inside the container on the center of the face of the center package in the container. 1/ Each thermocouple was taped in position, and it was noted at unloading that the position of each thermocouple had not shifted inside the container during the test. Figure 3 indicates the position of the thermocouples inside each trailer. Figures 4 and 5 show the interior of trailer A and the typical manner of stacking the cartons of TV dinners and pies.

TEST RESULTS

Figures 6 and 7 are graphs showing air and commodity temperatures of trailers A and B, respectively, after loading and enroute from Omaha to Dallas. The trailers traveled different routes beyond Dallas and data for that portion of the trips are therefore not shown on the graphs. However, all data are given for trailers A and B in tables 1 and 2, respectively.

The maximum temperature of the product in trailer A at 5:20 p.m. following loading, was 16.5° F. at the top front side of the load. The temperature of these boxes fell to -.5° F. by 6:45 a.m. the following morning. Earlier on June 22 at 3:45 a.m. the maximum commodity temperature of 8.5° F. was observed in the boxes at the bottom front side corner of the load. Before unloading at

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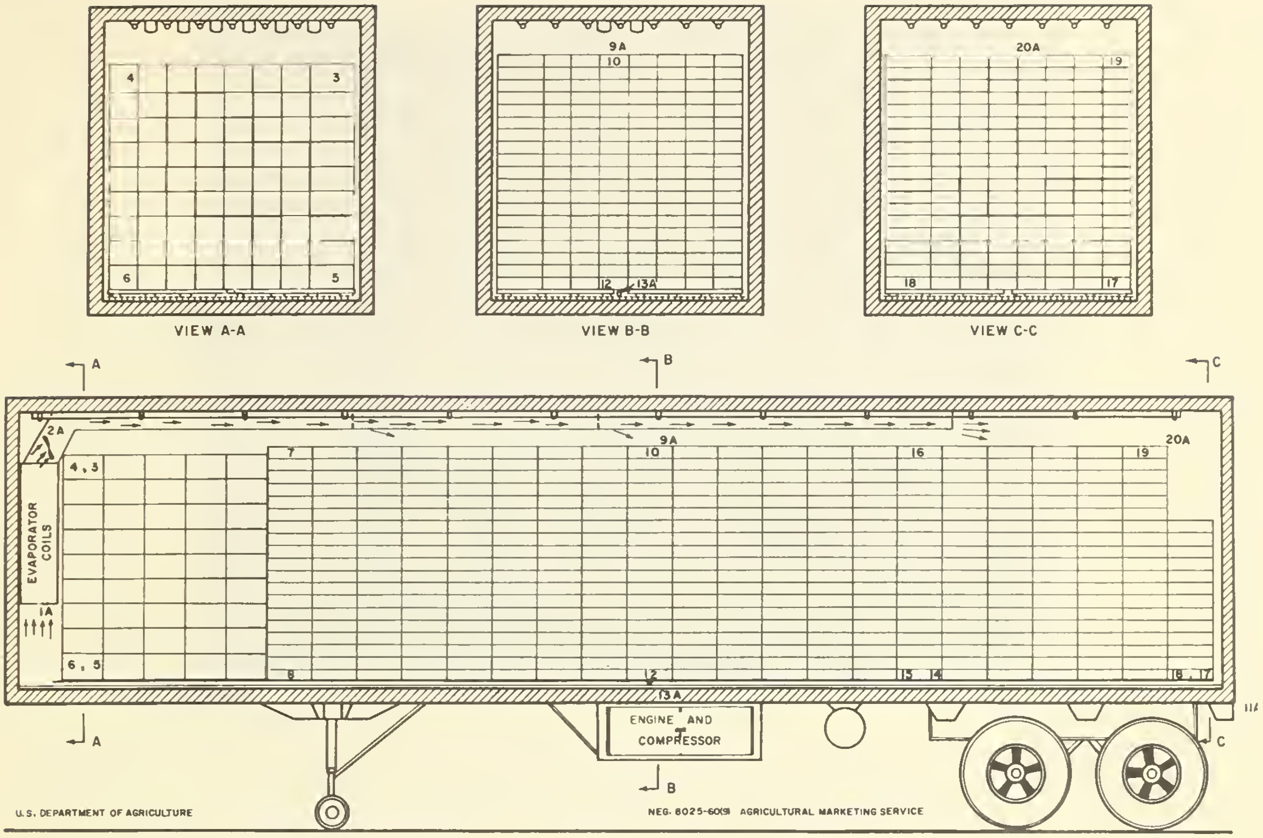
1/ Guadangi, D. G., and Jansen, E. F. Gaging Frozen Food Temperatures. Food Engin., July 1957.



No.	Position
1A.	Return air
2A.	Delivery air
3.	Top front right side
4.	Top front left side
5.	Bottom front right side
6.	Bottom front left side
7.	Top front quarter center
8.	Bottom front quarter center
9A.	Top middle center air
10.	Top middle center
11A.	Outside air (ambient)
12.	Bottom middle center
13A.	Bottom middle center air (under load)
14.	Bottom rear quarter right side
15.	Bottom rear quarter left side
16.	Top rear quarter center
17.	Bottom rear right side
18.	Bottom rear left side
19.	Top rear right side
20.	Top rear center air

Figure 3.--Location at which air and commodity temperatures were taken in each trailer. (Due to the wide variety of products loaded and differences in carton sizes, the boxes shown above are used merely to simulate loaded conditions.)

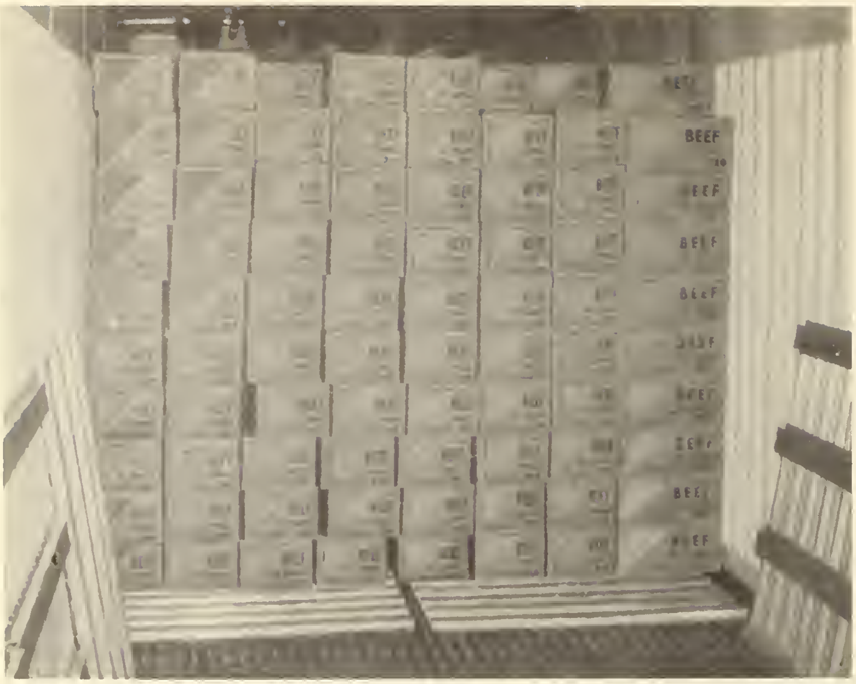


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Figure 4.--TV dinners stacked in front section of trailer A. Note vertical sidewall ribbing.

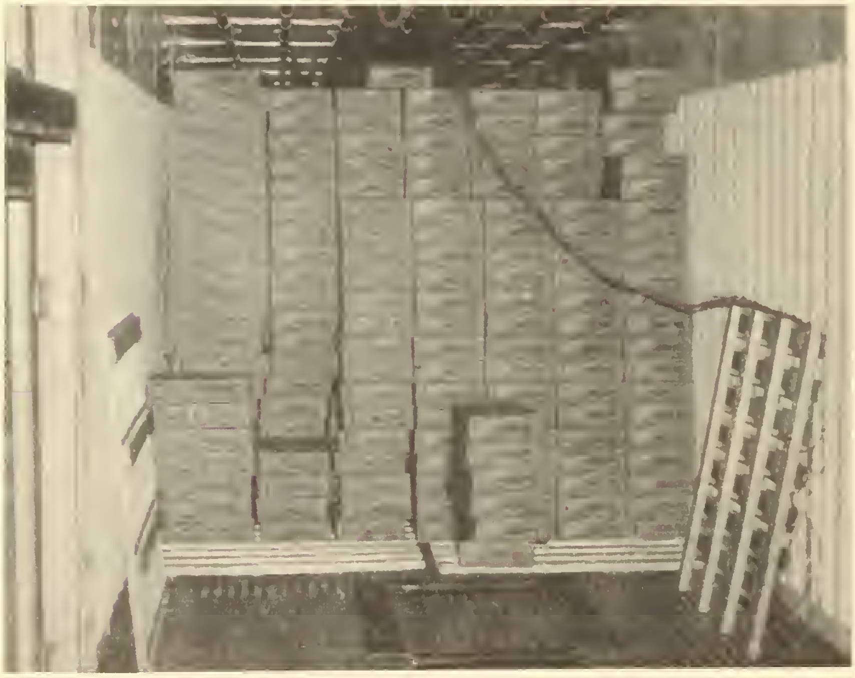

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Figure 5.--Chicken pies stacked in rear section of trailer A. Arrow indicates two air blast ducts.

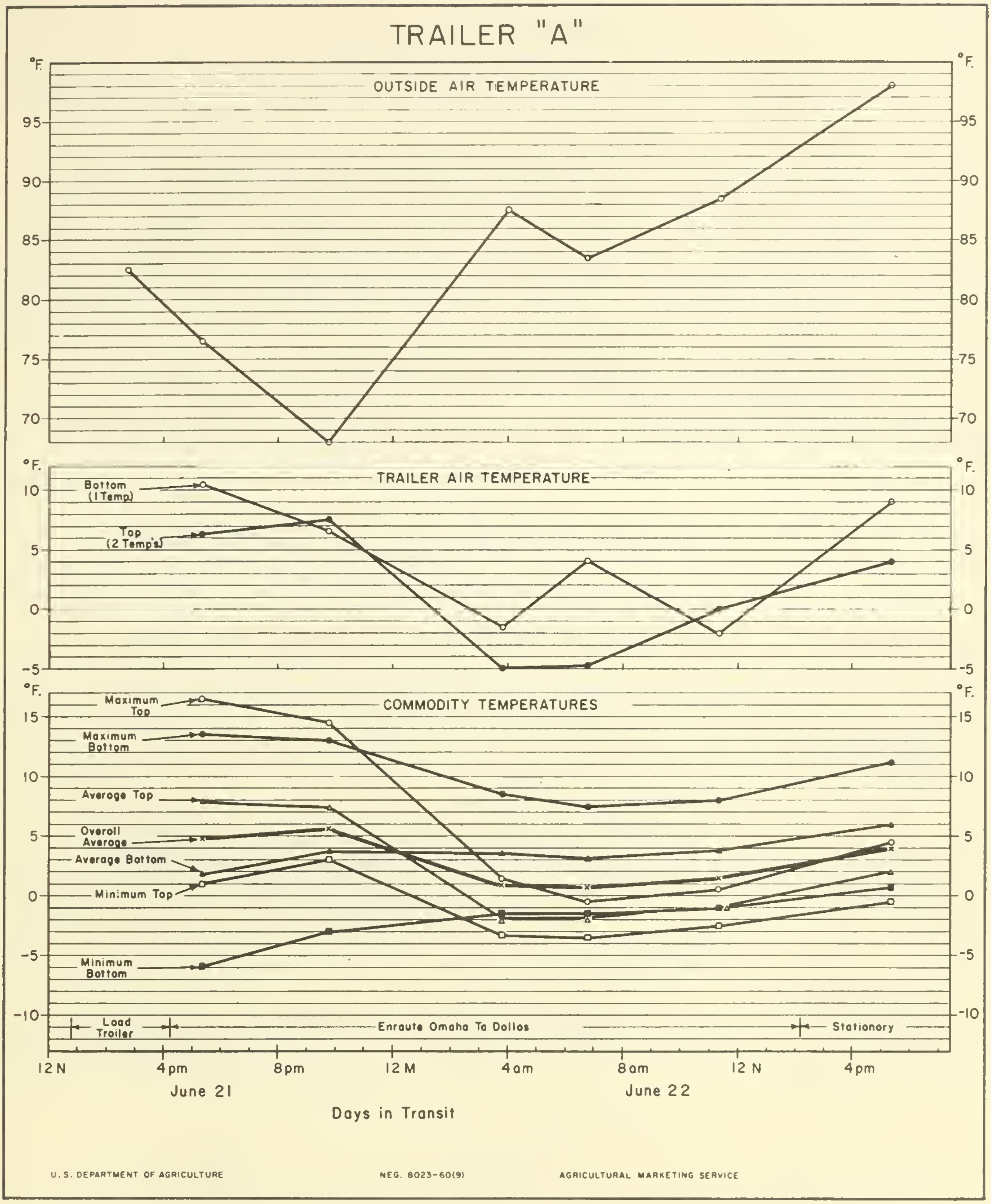

Figure 6.--Temperatures in trailer A.

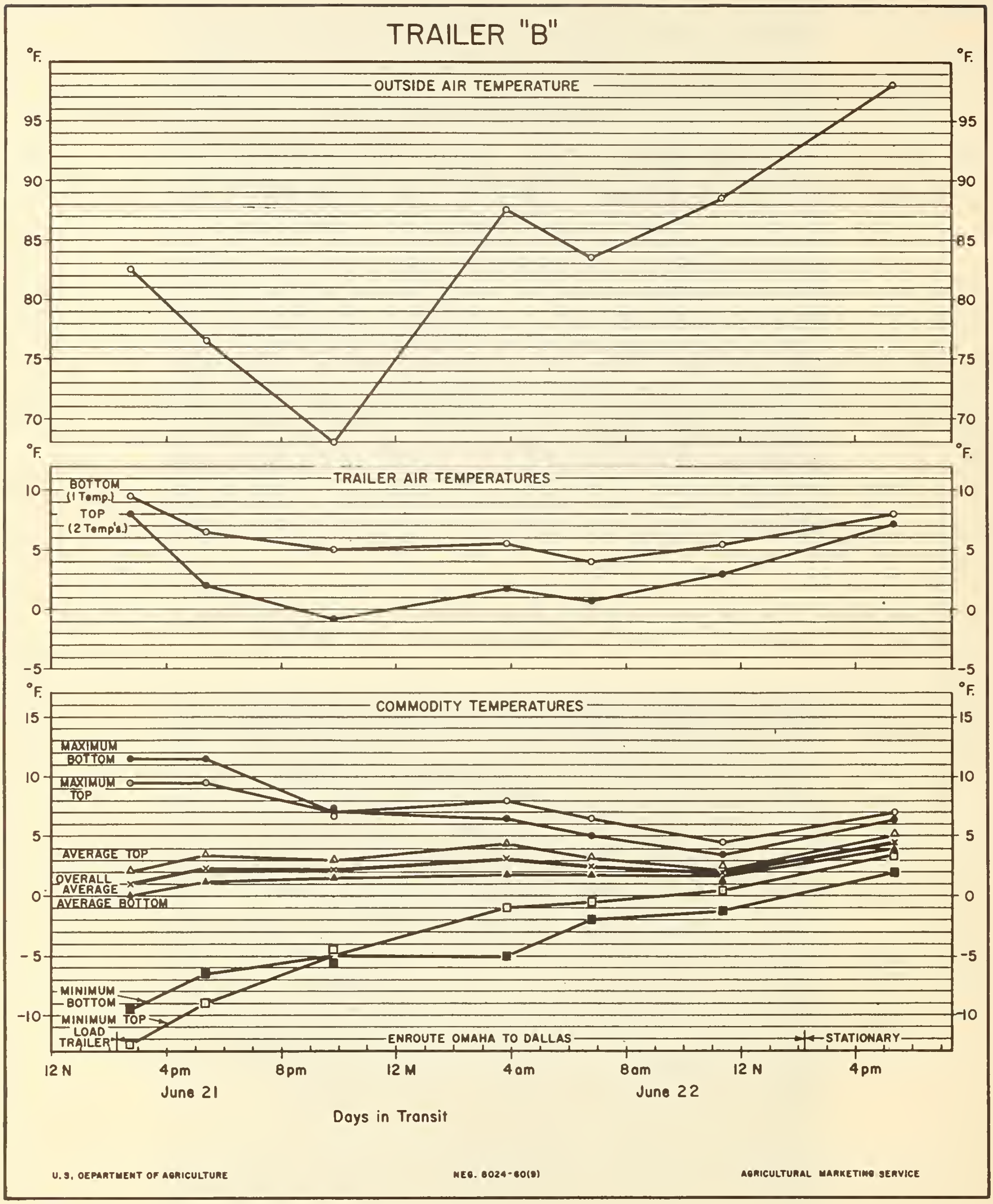

Figure 7.--Temperatures in trailer B.

7:05 a.m. on June 23 the maximum commodity temperature was 12° F. also at the bottom front side corner. The maximum commodity temperature after reaching a low of 7.5° F. remained between 6.5° F. and 8.5° F. above the average commodity temperature.

In trailer B the maximum temperature of the load fell from 11.5° F. at 5:20 p.m. after loading to 6.5° F. by 6:45 a.m. the following morning and continued to fall to research 4.5° F. at 11:20 a.m. These boxes located at the front side of the load were 6.0° F., 6.5° F. and 7.0° F. at unloading at 2:06 p.m., (27 hours later) when the maximum commodity temperature was 7.5° F. at the bottom rear corner. At 5:10 p.m. on June 22 and at unloading on June 23 the maximum commodity temperature was within 2.5° F. of the average commodity temperature.

The spread between maximum and minimum temperature of the cargo after loading in trailer A was 22.5° F. (-6.0 to +16.5° F.) which was reduced to a spread of 11.7° F. (-5 to +11.2° F.) to Dallas. Trailer B reduced its cargo temperature spread from 24.0° F. (-12.5 to +11.5° F.) to 5.0° F. (+2 to +7° F.) during the trip.

The overall average temperature (figs. 6 and 7) of the cargo was lowered during the trip in trailer A from 4.8° F. to 4.0° F. During the same period there was a rise in average temperature in trailer B from 2.3° F. to 4.5° F.

The average top commodity temperature was approximatley 6.0° F. higher than the average bottom commodity temperature in trailer A immediately after loading. However, this relation was reversed after about 5 hours and for the remainder of the trip the average top commodity stayed about 4.0° F. colder than the bottom. In trailer B the average bottom commodity temperature remained about one to two degrees below the average top commodity temperature throughout the trip.

Trailer B was unloaded at three points at Houston, Tex., and June 23. The average commodity temperature increased from 5.3° F. at 2:06 p.m., before the first unloading, to 9.9° F. at 6:35 p.m. at the final unloading. The maximum commodity temperature during the same 4½ hour period increased from 7.5° F. to 12° F. These temperature changes illustrate the difficulty of maintaining commodity temperatures when it is necessary to unload at several places.

The commodity temperatures in both trailers followed the same general trend as the trailer inside air temperatures. The average top air in both trailers was lower than the average bottom air with two exceptions in trailer A.

CONCLUSIONS

The average bottom commodity temperature in trailer B was maintained below that of trailer A throughout the test, apparently as a result of better distribution of chilled air and a better insulated floor. The temperature spread in trailer B was generally decreased throughout the test and was better than that of trailer A. The maximum temperature in trailer A was generally higher throughout the test than in trailer B, which maintained the maximum commodity temperature within 2.5° F. of the average commodity temperature during the latter part of the test. In both trailers, however, the maximum top and maximum bottom commodity temperatures were reduced for the overall test.

The average load temperature at Dallas was practically the same in both trailers. However, trailer A had a refrigeration unit rated at greater capacity than that of trailer B. This would indicate that trailer B was more effectively insulated than trailer A.

There was an increase in inside air and average commodity temperatures of the trailers after noon during the hot part of the day on June 22. This would indicate that the refrigerating capacity of the units on both trailers was not great enough to overcome the heat load of the sun and outside air above 95° F. without a gradual increase in commodity temperatures.

It was noted during the test that the defrost cycle was initiated and terminated manually by the driver throwing the defrost switch. While the initiation of the defrost cycle was accomplished easily, the termination of the defrost cycle at the moment when the coil was freed of frost was a matter of guesswork on the part of the driver as he drove down the highway. An automatic defrost cycle would improve the overall efficiency of operation of the refrigeration unit and assure that the refrigeration cycle was turned back on as soon as the accumulation of ice and frost on the coils had been dissipated.

Trailer A and B differed considerably in basic points of design. The type of insulation used in each trailer, the thickness of the floor insulation (2 inches thicker in trailer B), the air space under the load (1/2 inch more in trailer B), the inside wall ribbing (diagonal ribbing in trailer B), the cross-ventilating type floor (holes on 2-inch centers in trailer B), are major design variations which account for the better operating performance of trailer B. 2/

These two refrigerated trailers represent advances in design and construction which will help carriers to maintain frozen foods closer to 0° F. than has been previously possible. Additional tests will be made on other late model equipment to determine those features which are improvements and of interest to the industry.

2/ A study of the methods by which the distribution of chilled air around the cargo in trailers could be made more effective in maintaining desired cargo temperatures is now being conducted jointly by the National Bureau of Standards and the U. S. Department of Agriculture.

APPENDIX

Table 1.--Air and Commodity temperatures recorded during tests of trailer "A" from Omaha, Nebr., to Garland, Tex.,--June 21-23, 1960

Date and time	Location	Outside temp. 11A	Air temperatures 1/					Top commodity temperatures 1/									Bottom commodity temperatures 1/											Overall average commodity	Overall spread
			Return air 1A	Delivery air 2A	9A	13A 2/	20A	3	4	7	10	16	19	Max. top	Min. top	Avg. top	5	6	8	12	14	15	17	18	Max. bot	Min. bot	Avg. bot		
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
6/21-11:15 a.m.	Omaha, Nebr.	Trailer arrived at loading dock precooled to 15° F. (Approximatley 250 pounds of dry ice used for precooling)																											
6/21-12:45 p.m.	" "	Loading started																											
6/21- 4:15 p.m.	" "	Loading completed																											
6/21- 5:20 p.m.	" "	73.0	8.5	-.5	6.0	10.5	4.5	16.5	16.5	6.5	1.0	1.5	+5.0	16.5	+1.0	7.9	12.5	13.5	3.0	-6.0	.5	2.5	-1.5	3.0	13.5	-6.0	+1.8	4.8	22.5
6/21- 8:20 p.m.	---	Started defrosting coil																											
6/21- 8:50 p.m.	---	Finished defrosting coil																											
6/21- 9:45 p.m.	Sabetha, Kans.	66.0	10.0	2.0	7.0	6.5	5.6	13.5	14.5	3/	3.0	3.5	6.5	14.5	3.0	7.4	13.0	13.0	5.0	-3.0	5.0	6.0	1.0	1.5	13.0	-3.0	3.8	5.6	17.5
6/22- 3:45 a.m.	Parsons, Kans.	86.0	-2.5	-10.0	-7.5	-1.5	3/	1.5	-2.5	3/	-.5	-3.2	-2.5	1.5	-3.2	-1.8	8.5	7.5	4.5	-1.5	5.0	3/	3.0	3.5	8.5	-1.5	3.5	.9	11.7
6/22- 3:50 a.m.	" "	Started defrosting coil																											
6/22- 4:20 a.m.	---	Finished defrosting coil																											
6/22- 6:45 a.m.	Chouteau, Okla	80.0	-1.5	-8.5	-6.0	4.0	-6.5	-.5	-.5	3/	-1.5	-3.5	-2.5	-.5	-3.5	-1.8	7.5	6.0	3.5	-1.5	5.0	3/	3.5	4.5	7.5	-1.5	3.1	.7	11.0
6/22- 8:00 a.m.	Started defrosting coil																												
6/22- 8:30 a.m.	Finished defrosting coil																												
6/22-11:20 a.m.	Sherman, Tex.	84.5	1.5	-4.5	-1.5	-2.0	3/	.0	2/	3/	-1.6	-2.5	.5	.5	-2.5	-.9	8.0	6.0	3.5	-1.0	6.0	3/	5.5	6.5	8.0	-1.0	3.8	1.5	10.5
6/22- 1:15 p.m.	Started defrosting coil																												
6/22- 1:45 p.m.	Finished defrosting coil																												
6/22- 5:10 p.m.	Dallas, Tex.	100	3/	-.5	4.0	9.0	3/	3.0	4.5	3/	-.5	.5	4.5	4.5	-.5	2.0	11.2	9.0	5.0	.7	8.0	3/	8.5	10.0	11.2	.7	6.0	4.0	11.7
6/22- 5:00 p.m.	" "	Started defrosting coil																											
6/22- 6:00 p.m.	" "	Finished defrosting coil																											
6/23- 2:00 a.m.	" "	Started defrosting coil																											
6/23- 2:30 a.m.	" "	Finished defrosting coil																											
6/23- 7:05 a.m.	Garland, Tex.	81.0	3/	-9.5	-6.5	6.5	-6.5	-.5	1.0	2.5	.0	-2.0	-.5	2.5	-2.0	.0	12.0	8.5	6.5	3.2	9.0	5.5	9.0	10.6	12.0	3.2	7.0	3.5	14.0
6/23- 7:10 a.m.	" "	Unloading began																											
6/23-10:06 a.m.	" "	---	---	---	---	---	---	13.0	11.5	4.5	---	---	---	---	---	---	13.0	10.0	6.5	---	---	---	---	---	---	---	---	---	---
6/23-11:00 a.m.	" "	Unloading completed																											

1/ See figure 3 for location of readings.
2/ 13A is located beneath floor rack.
3/ Unable to obtain reading.

Table 2.--Air and commodity temperatures recorded during tests of trailer "B" from Omaha, Nebr., to Garland, Tex.,--June 21-23, 1960

Date and time	Location	Outside temp. 11A	Air temperatures at location 1/					Top commodity temperatures 1/									Bottom commodity temperatures 1/											Overall average commodity	Overall spread
			Return: air 1A	Delivery: air 2A	9A	13A 2/	20A	3	4	7	10	16	19	Max. top	Min. top	Avg. top	5	6	8	12	14	15	17	18	Max. bot	Min. bot	Avg. bot		
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
6/21- 7:45 a.m.	Omaha, Nebr.	Trailer arrived at loading dock precooled to 15°F. (Approximatley 200 pounds of dry ice used for precooling)																											
6/21- 8:10 a.m.	" "	Loading started																											
6/21- 2:15 p.m.	" "	Loading completed																											
6/21- 2:45 p.m.	" "	82.5	7.5	3.5	8.0	9.5	8.5	8.5	6.5	9.5	-2.0	2.5	-12.5	9.5	-12.5	2.0	6.5	11.5	4.5	-1.5	-3.5	-7.5	-9.5	-7.5	11.5	-9.5	.0	1.0	24.0
6/21- 5:20 p.m.	" "	80.0	2.5	2.0	2.0	6.5	1.5	8.5	7.5	9.5	.5	4.0	-9.0	9.5	-9.0	3.5	7.0	11.5	4.5	.5	-1.5	-4.5	-6.5	-6.5	11.5	-6.5	1.2	2.3	20.5
6/21- 9:45 p.m.	Sabetha, Kans.	69.5	2.0	-4.5	-3.0	5.0	-1.3	7.0	7.0	6.0	1.5	1.5	-5.0	7.0	-5.0	3.0	6.5	7.0	3.5	1.5	.5	-1.5	-4.0	-5.0	7.0	-5.0	1.5	2.2	12.0
6/21-10:15 p.m.	---	Started defrosting coil																											
6/21-10:45 p.m.	---	Finished defrosting coil																											
6/22- 1:30 a.m.	---	Started defrosting coil																											
6/22- 2:00 a.m.	---	Finished defrosting coil																											
6/22- 3:45 a.m.	---	89.0	1.0	.5	2.0	5.5	2.5	8.0	6.5	6.2	2.5	4.2	-1.0	8.0	-1.0	4.4	6.0	6.5	3.5	1.5	1.7	.0	-5.0	-2.0	6.5	-5.0	1.8	3.1	13.0
6/22- 6:45 a.m.	Chouteau, Okla	87.0	.5	-1.0	.5	4.0	1.5	6.5	5.5	4.0	2.0	2.2	-.5	6.5	-.5	3.2	5.0	5.0	2.7	1.2	2.0	-.5	-.5	-2.0	5.0	-2.0	1.8	2.5	8.5
6/22-11:20 a.m.	Sherman, Tex.	92.5	4.0	.0	1.5	5.5	3.5	4.5	4.5	2.0	1.0	1.0	.5	4.5	.5	2.2	3.0	3.5	2.5	1.0	2.0	1.0	1.0	-1.2	3.5	-1.2	1.7	2.0	5.7
6/22-11:30 a.m.	---	Started defrosting coil																											
6/22-12:45 p.m.	---	Finished defrosting coil																											
6/22- 5:10 p.m.	Dallas, Tex.	96.0	8.0	3.5	5.5	8.0	8.0	7.0	6.0	5.0	3.5	5.0	4.0	7.0	3.5	5.1	5.0	6.5	5.0	2.5	4.0	3.5	5.0	2.0	6.5	2.0	4.0	4.5	5.0
6/23- 8:00 a.m.	---	Started defrosting coil																											
6/23- 8:45 a.m.	---	Finished defrosting coil																											
6/23- 2:06 p.m.	Houston, Tex.	88.0	8.0	2.5	4.0	9.5	6.5	6.0	7.0	3.5	3.5	4.5	6.5	7.0	3.5	5.1	4.5	6.5	6.0	4.5	7.2	6.5	7.5	5.5	7.5	4.5	5.6	5.3	4.0
6/23- 2:10 p.m.	" "	Started unloading at first stop																											
6/23- 3:20 p.m.	" "	Finished unloading at first stop																											
6/23- 4:35 p.m.	" "	Started unlosding at second stop																											
6/23- 4:35 p.m.	" "	83.0	22.5	14.0	54	28.5	---	9.0	8.5	7.8	7.0	---	---	9.0	7.0	8.1	6.0	9.0	10.0	6.0	---	---	---	---	10.0	6.0	7.8	8.0	4.0
6/23- 6:05 p.m.	" "	Finished unloaidng a second stop																											
6/23- 6:35 p.m.	" "	Started final unloading																											
6/23- 6:35 p.m.	" "	---	---	---	---	---	---	10.5	9.5	---	---	---	---	---	---	10.0	7.5	12.0	---	---	---	---	---	---	---	---	9.8	9.9	4.5
6/23- 7:30 p.m.	" "	Finished unloading																											

1/ See figure 3 for location of readings.
2/ 13A is located beneath floor rack.